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OMNI DIRECTIONAL LINE FOLLOWING MOBILE ROBOT

HASRIL IZHAM B ISMAIL @ ABU HASSAN

A thesis submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Engineering (Electrical - Mechatronics)

Faculty of Electrical Engineering,

Universiti Teknologi Malaysia

MAY 2011

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DEDICATION

To my beloved friends and family members for their warmest support

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I would like to take this opportunity to express my sincere appreciation to my Final Year Project (FYP1) supervisor, En Mohamad Amir bin Shamsudin and (FYP2) supervisor, Dr Yeong Che Fai. I would like to thank them for their supervision, guidance and support throughout this project. Their ideas and suggestions were invaluable assets to me whenever problems arose in the project.

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Last but not least, I would like to express my appreciation to anybody who directly or indirectly has contributed to the success of this project.

ABSTRACT

A variety of designs of mobile robot have been developed in recent years in order to improve their omni directional mobility and practical applications. Omni directional mobile robot has vast advantages over conventional design likes differential drive in term of mobility in congested environments. The main purpose of this research is to design, develop and implement an Omni Directional Line Following Mobile Robot with transwheels for autonomous navigation. Using these transwheels, the mobile robot is provided with three degree of freedom (DOF) mobility. In this project, microcontroller PIC16F777 is used as the brain of the robot to control the robot's movements where all data is processed. To move in omni directional, 3 transwheels are used. The three transwheels are driven by three DC Geared motor independently. IR sensors are used to detect the line. MPLAB IDE is used to write the source code and then generate the HEX file. The HEX file is then flashed into the PIC using the USB Programmer. Experiments were performed to analyze the motion characteristic of the mobile robot motions. As the result, the Omni Directional Line Following Mobile Robot able to move in omni directional and follow the line in particular direction that has been assign.

ABSTRAK

Kepelbagaian rekabentuk robot bergerak telah dibangunkan kebelakangan ini dalam usaha memperbaiki keupayan pergerakannya dan aplikasi praktikal. Robot berarah omni mempunyai kelebihan berbanding robot lain yang terbatas kerana keupayaannya bergerak dalam persekitaran yang sesak. Objektif utama penyelidikan ini adalah merekabentuk, membangun dan mengimplimentasikan robot berarah omni mengikut jalan yang dilengkapi roda transwheels untuk bergerak secara berpanduan. Dengan menggunakan tayar transwheels, robot bergerak memberikan tiga darjah kebebasan dalam pergerakan. Dalam projek ini, cip PIC16F777 digunakan sebagai pusat kawalan utama robot untuk mengawal pergerakan robot di mana semua data diproses. Untuk bergerak secara omni, tiga tayar transwheels digunakan. Ketiga-tiga tayar transwheels ini dipandu oleh tiga motor arus terus secara berasingan.IR sensor digunakan untuk mengesan jalan. MPLAB IDE digunakan untuk menulis kod program dan kemudian menghasilkan fail HEX. File HEX ini kemudian akan dimasukkan ke cip menggunakan alat program USB. Ujikaji telah dijalankan untuk menganalisa ciri-ciri pergerakan robot bergerak. Hasilnya, robot berarah omni mengikut jalan berupaya bergerak secara omni dan mengikut jalan dalam arah yang ditetapkan.

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LIST OF ABBREVIATION

A	-	Ampere
ADC	-	Analog to Digital Converter
AUSART	-	Addressable Universal Synchronous Asynchronous Receiver Transmitter
C	-	Computer
CD	-	Compact Disc
DC	-	Direct Current
DOF	-	Degree Of Freedom
FYP	-	Final Year Project
I/O	-	Input/Output
IR	-	Infra Red
k	-	Kilo
kg	-	Kilogram
LiPo	-	Lithium Polimer
mA	-	mili Ampere
mAh	-	mili Ampere hour
MHz	-	Mega Hertz
mm	-	Millimeter
mNm	-	miliNewtonmeter
MSSP	-	Master Synchronous Serial Port
PIC	-	Peripheral Interface Controller
PSP	-	Parallel Slave Port
RM	-	Ringgit Malaysia
RPM	-	Revolution Per Minute
s	-	second
TTL	-	Transistor-transistor Logic
V	-	Voltage

LIST OF APPENDIXES

CHAPTER 1

INTRODUCTION

1.1 Project Background

Omni directional is described as the ability of a system to move instantaneously in any direction from any configuration. Omni directional mobile robot has many advantages compared to ordinary mobile robot in term of its movement. These abilities can overcome the challenges in everyday life. It can move in any direction without having to turn relative to its base. For example, to move sideways a differential drive mobile robot can turn 90 degrees, either to left side or right side. Many design of omni directional have been proposed nowadays because of its ability to move in special directions.

This mobile robot has three degrees of freedom, i.e. two dimensional linear motions and one dimensional rotational motion. There are three universal wheels mounted along the edge of the robot chassis 120° apart from each other, and each wheel has a set of passive rollers aligned with its rim. Because of its special mechanism, the robot is able to simultaneously rotate and translate.

Omni directional line following mobile robot is a mobile robot that has the ability to move in omni directional while follow the line assign to it as it path. This mobile robot consists of 3 transwheels attached to the mobile robot base. It has sensors to detect the given line, and make it possible to follow the line.

1.2 Problem Statements

Current mobile robot use conventional wheels to move. It has to turn its mobile robot base to turn either to the left or right. It takes more times and spaces to move the mobile robot base to the desired place. These problems can be solved by using an omni directional mobile robot. This mobile robot doesn't have to turn its body respective to the direction of the desired place. This kind of movement is more stable and easier to move without changing the base. This mobile robot operates autonomously. So it will not require someone to control its movement. Because of its mobility, it will have many applications either in home, industrial or other area.

1.3 Objectives of Project

The main objective of this project is to design and construct a mobile robot with an ability to move in omni directional. The mobile robot is made by 2mm thickness aluminium. 3 transwheels are used so that it will move in omni directional. Each transwheel is driven by a DC geared motor.

Second objective is to enable line following ability of this mobile robot. IR sensor is used to detect the line. 12 set of IR sensor is used so that it can sense the line that I have assigned.

1.4 Scopes of Project

The scopes of this project are outlined as following:

1. Design and construct omni directional mobile robot using the transwheels.
2. Moving in fully omni directional way.
3. Omni directional robot able to detect and follow the given line track.

1.5 Thesis Layout

This thesis consists of 5 chapters and each chapter is briefly discussed here. Chapter 1 gives an introduction and overview of this project. The project's problem statements, objectives and scopes also included in this chapter. Chapter 2 presents some of the literature reviews relating to this project. It discussed some documentation of previous students' work and others.

Chapter 3 discussed the methodology of the project. Hardware and software methodology is explained in this chapter. Chapter 4 presents the result of the developed system and its limitation. Chapter 6 covers the conclusion and the recommendations for future development.

1.6 Planning

In order to complete this project, proper in planning management will ensure the task is done based on the schedule. Figure 4.1 below shows the Gantt chart of this project from semester 1 to semester 2.

Table 1.1: Gantt chart Of the Project Schedule for FYP

Task / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Topic research and proposal															
Literature review															
Hardware design															
Hardware part's purchase															
Hardware implementation															
FYP1 presentation															
Report writing															

a) FYP 1

Task / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hardware completion																		
Software implementation (movement)																		
Software implementation (IR sensor)																		
Testing and troubleshoot																		
Thesis writing																		
FYP2 presentation																		
Thesis compilation																		

b) FYP 2

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Reviewing similar projects done by other researchers can be a guideline to this work. The literature review is divided into two parts which are omni directional wheel design and omni directional vehicle.

2.2 Omni Directional Wheel Design

It is important to choose the right omni directional wheel design in order to move in omni directional. As there are many kinds of omni directional wheels design in the market, choosing the right type of wheel design based on the requirement and the usage of the mobile robot is important. There are two types of omni directional wheel design. They are conventional wheels design and special wheels design. But this project uses the special wheels design only.

2.2.1 A Design of Omni Directional Mobile Robot

This is a project group by Jefri Efendi Mohd Salih, Mohd Rizon Mohd Juhari, Sazali Yaacob and Abdul Hamid Adom from Kolej Universiti Kejuruteraan Utara Malaysia (KUKUM) on 2006.

The project uses Mecanum wheels design. Mecanum wheel is based on the principle of a central wheel with a number of rollers placed at an angle of 45° around the periphery of the wheel. Depending on each individual and speed wheel direction, the resulting combination of all these forces produces a total force vector in any desired direction thus allowing the platform to move freely in direction of resulting force vector, without changing the direction of the wheel. Using the mecanum wheel, slipping is a common problem as it has only one roller with a single point of ground

contact at any one time. Due to the dynamics of the mecanum wheel, it can create force vectors in both the x and y-direction while only being driven in the y-direction. Positioning four mecanum wheels, one at each corner of the mobile base, allows net forces to be formed in the x, y and rotational direction. Figure 2.1 shows the mecanum wheel and Figure 2.2 shows the design of the mobile robot using the mecanum wheel.

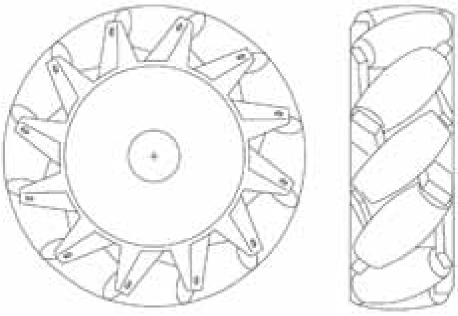


Figure 2.1: The Mecanum wheel

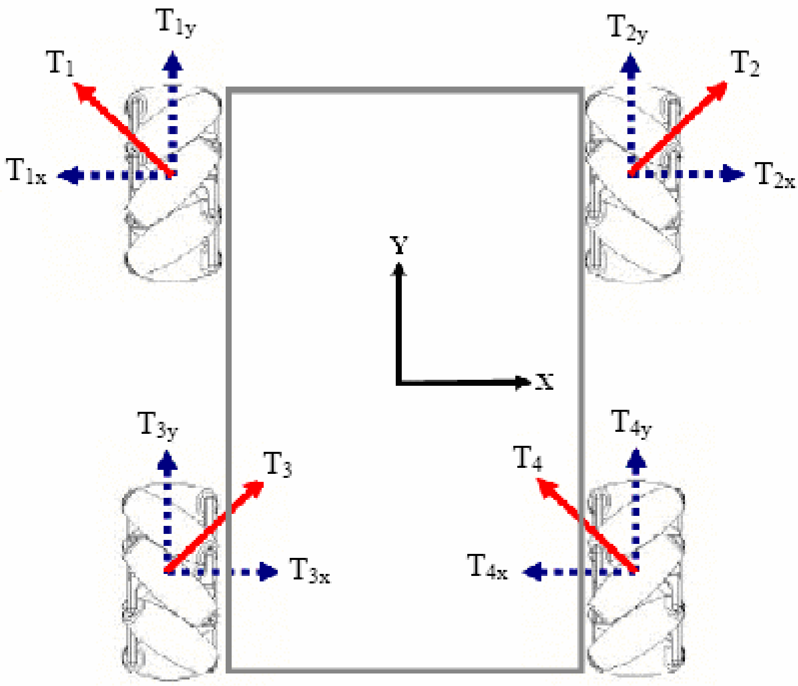


Figure 2.2: Design of mobile robot using the mecanum wheel

2.2.2 Design of an omni directional robot for FIRA ROBOSOT.

This project constructed by a group of students from Korea Advance Institute of Science and Technology. They were Naveen Suresh Kuppuswamy, Se-Hyoung Cho, Daniel Stonier, Sung-Lok Choi and Jong-Hwan Kim.

The transwheel's unique design contains eight free-turning rollers perpendicular to the axle arranged around the transwheels periphery. The design combined with the rotation of the wheel body provides the ability to move in any direction. It can be used to design either 3 transwheels or 4 transwheels.

To design a 3 transwheels mobile robot, the position of the 3 transwheels must be 120º apart while 4 transwheels have to be 90º apart. The transwheels can be drive by the DC geared motor or the servo motor individually. To prescribed robot's movement, the kinematic relate to the primary variables which are the angular positions and velocities of the wheel shafts needs to be developed. Figure 2.3 and Figure 2.4 below show the design of mobile robot using 3 transwheels and 4 transwheels.

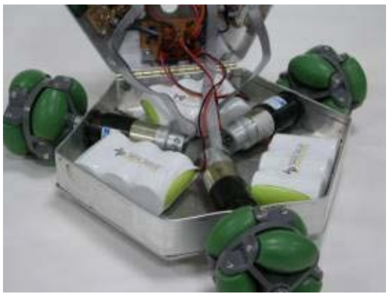


Figure 2.3: 3 transwheels

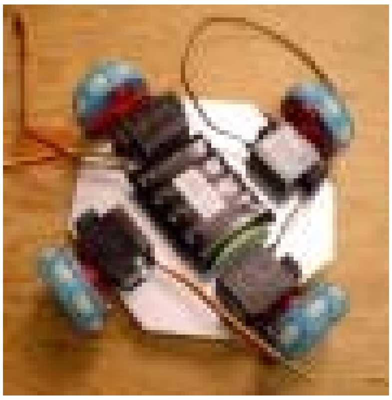


Figure 2.4: 4 transwheels

2.3 Omni Directional Vehicles

Omni directional mobile robots could perform important tasks in environments congested with static and/or dynamic obstacles and narrow aisles, such as those commonly found in offices, factory, house and other places. Current wheeled vehicle designs based on skid steering have limited mobility due to the non-holonomic constraints of their wheels.

2.3.1 The Omni Directional Writobot by Muhamad Nabil bin Mansor (2007/2008)

The omni directional writobot is omni directional vehicle that enable to leave its trails similar to writing behavior and to point some coordinate on a surface. Writobot is designed on three legs. Each leg is 120º apart. Each leg needs a castor and a castor needs 2 actuators (servo and stepper motor) to makes it move in omni

directional. Servo motor used to steer the robot movement while stepper motor used to rotate the wheel to move the robot. To move the marker pen up and down, writobot uses a computer CD drive that has been modified. This Writobot moves in omni directional by using the conventional wheels design. Figure 2.5 shows the design of omni directional Writobot.

Figure 2.5: Omni directional Writobot

The disadvantage of this project is higher cost because each leg needs 2 motors which are servo motor and stepper motor.

2.3.2 Omni Directional Mobile Home Care Robot

This project is design by a group of Hsu-Chih Huang, Chia-Ming Chen, and Tung-Sheng Wang from Department of Electrical Engineering, National Chung-Hsing University in 2006. This project also wins the third place in the mobile robot contest.

The robot provides home care for the disabled and improves their quality of life. The disabled person has to grab the article’s image in the camera and the system directs the platform and arm to pick up the object. This robot uses 3 transwheels design in order to move in omni directional. The transwheels are controlled by three servo motors independently. The robot used its network camera to detect image and robot arm to pick up objects. Figure 2.6 shows the figure of omni directional mobile home care robot.

Figure 2.6: Omni directional mobile home care robot

The disadvantage of this robot is it can’t rotate the transwheels continuously because it is driven by the servo motor. The servo motor can’t rotate continuously, but it rotates at 180° only.

2.3.3 Moving Target Tracking of Omni Directional Robot with Stereo Cameras

This project was done by Jun Ming Kuang, Ming Liu and Xiang Lin from Department of Electrical and Computer Systems Engineering, Monash University, Australia in 2006.

This robot has stereo cameras for target tracking purpose and move to the target in omni directional. It uses 3 transwheels. The transwheels are driven by 3 DC motors. It uses the stereo cameras to track the target and moving towards the target. Figure 2.7 shows the figure of moving target tracking of omni directional robot with stereo cameras.

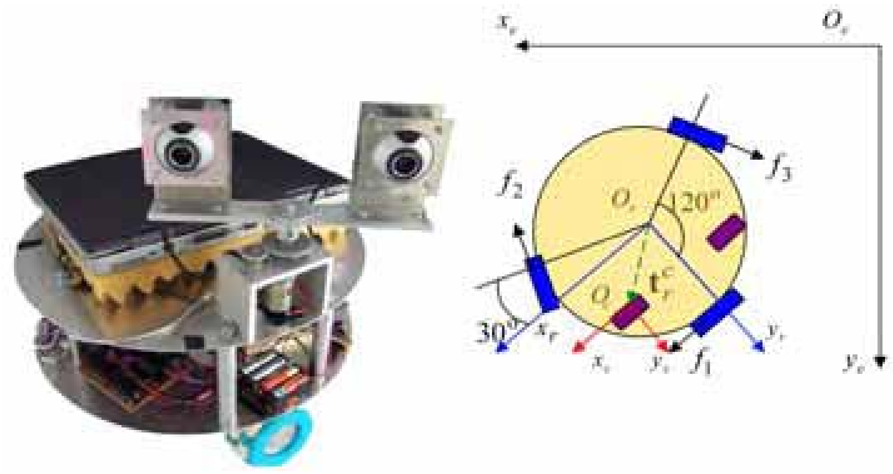


Figure 2.7: Moving target tracking of omni directional robot with stereo cameras

2.3.4 Omni Directional Mobile Robot using Mecanum Wheel

This project was developed by Jefri Efendi Mohd Salih, Mohd Rizon Mohd Juhari, Sazali Yaacob and Abdul Hamid Adom from Kolej Universiti Kejuruteraan Utara Malaysia (KUKUM) in 2006.

The robot uses 4 custom-made mecanum wheels. The mecanum wheels consist of nine rollers. The angle between the rollers and hub axes is 45°. All mecanum wheels are independently controlled by 4 DC geared motor. Using 4 mecanum wheels provides omni directional vehicle without needing a conventional steering system.

Depending on each individual wheel direction and speed, the resulting combination of all these forces produce a total force vector in any desired direction, without changing of the wheels themselves. Figure 2.8 shows the force vector of the mecanum wheel while Figure 2.9 shows the design of omni directional mobile robot.

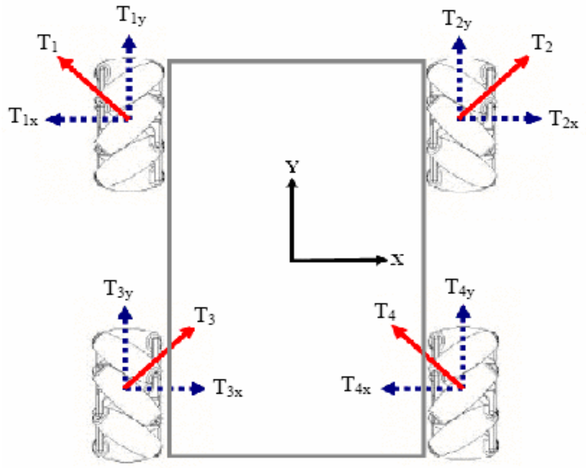


Figure 2.8: Force vector of mecanum wheel

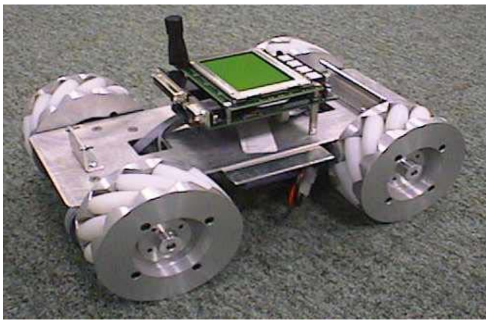


Figure 2.9: Omni directional mobile robot

2.4 Summary of Chapter 2

The literature review done in this chapter gives more knowledge on the omni directional movement. There are two types of special wheels, and the design construction of the wheels. From past projects, I also discovered the advantages and the disadvantages of this type of mobile robot. Their strengths and weakness are compared and analyzed to discover the most appropriate specification and features to be met in this project.

CHAPTER 3

METHODOLOGY

Figure 3.1 shows the steps taken to develop the omni directional line following mobile robot.

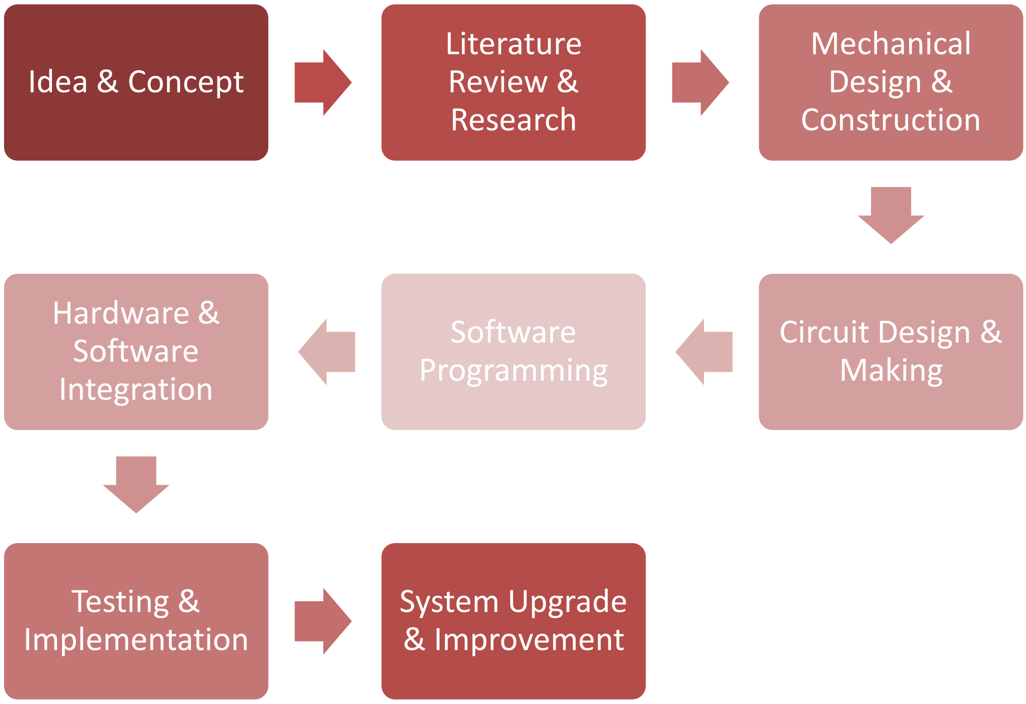
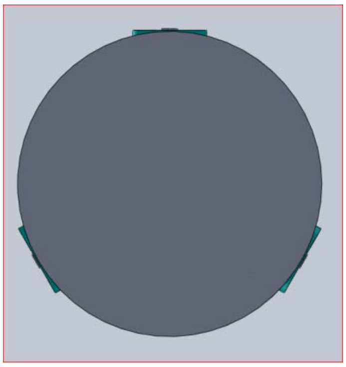


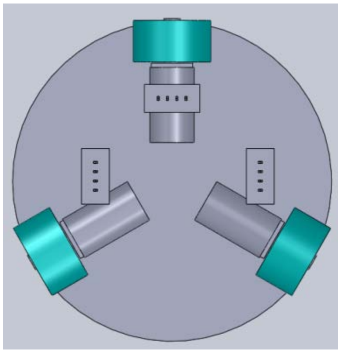
Figure 3.1: Flow chart of methodology

The idea comes from the earlier line following mobile robot. This project improves the line following mobile robot by using the transwheels that has the ability to move in omni directional. Literature review on past project was done in the previous chapter.

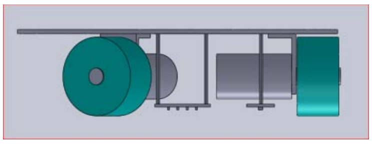
The next step was designing and implementing mechanical structure of the mobile robot base. The designing work was done by using SolidWorks software. The design includes the base, transwheels and the DC geared motor. Continuous adaption and improvement was made alongside this step. Figure 3.2 shows the plan, bottom and side view of the mobile base using the SolidWorks software.



a) Plan view



b) Bottom view



c) Side view

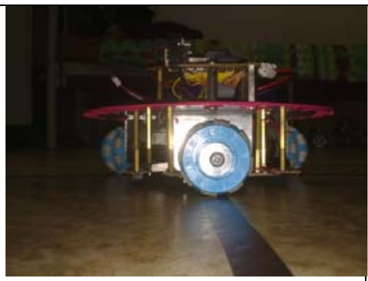
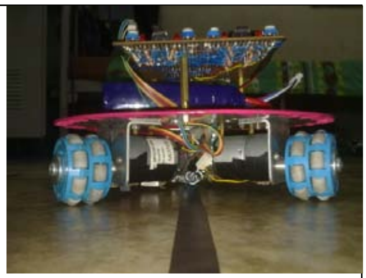
Figure 3.2: View of mobile base

After that main circuit was design by using Proteus software. The circuit was made according to the schematic drawn earlier. Later, the software part was started whereby the C programming language was written in MPLAB IDE software.

The following step is the most important stage which is the integration between the hardware and software that were done earlier. The validity and feasibility of the programming codes were tested and evaluated by trial-and-error method. Finally, the system was upgraded and improved to better the overall performance of the omni directional line following mobile robot.

3.1 Hardware and Mechanical Design

The mechanical design of the base of omni directional line following mobile robot was first being developed in FYP 1. Figure 3.3 below shows picture of different views of the mobile robot.

		
Plan View	Front View	Back View

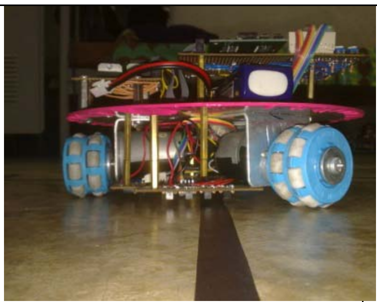
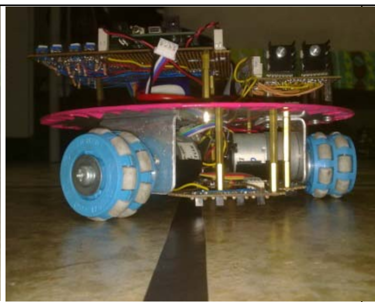
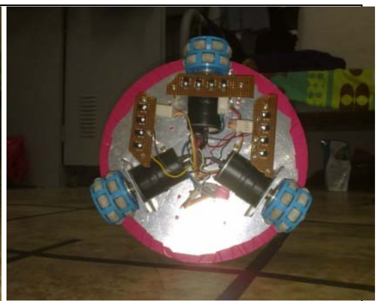
		
Left View	Right View	Bottom View

Figure 3.3: Different View of Mobile Base

The mobile robot base was made by 2 mm thick aluminium and radius of 110 mm. The based consists of 3 transwheels paired with 3 DC geared motor. To attach the transwheels and the DC geared motor, a custom made coupling is needed so that the transwheels can be driven by the DC gear motor. The transwheels are placed 120° apart.

12 set of IR sensors is placed at the bottom of the mobile robot. The IR sensor is used to make the line tracking feature. There are 3 pairs of IR sensor. Each pair consists of 4 set of IR sensor. The sensor is placed at the bottom of the mobile base. Figure 3.4 shows the position of the IR sensor.

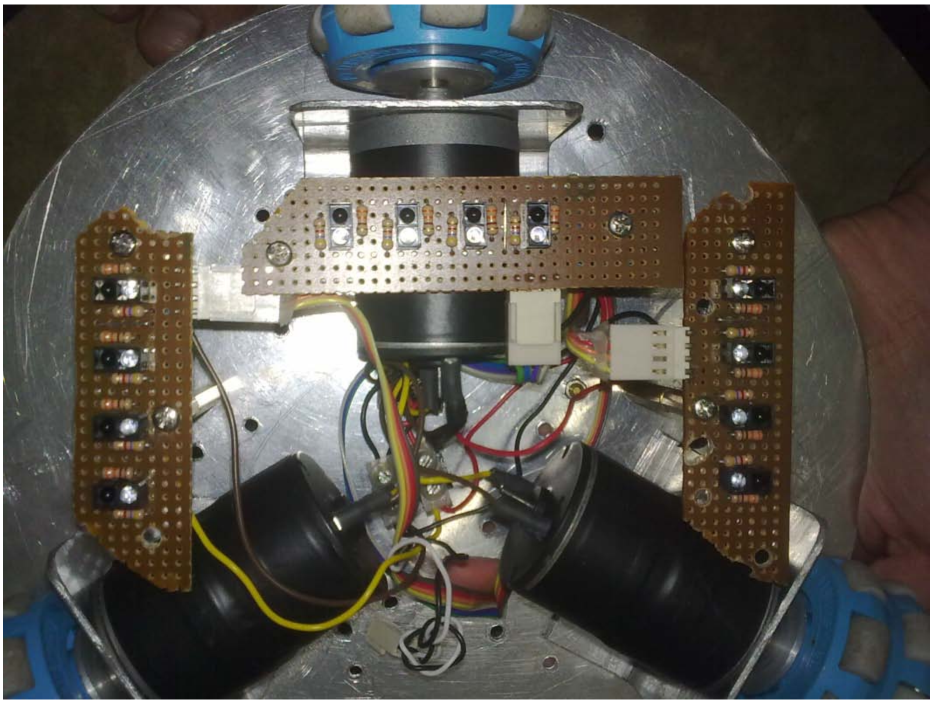


Figure 3.4: Position of the IR sensor

3.1.1 Transwheels

The Transwheel’s unique design contains eight free-turning rollers perpendicular to the axle arranged around the Transwheel periphery. This distinct design combined with the rotation of the wheel body provides the ability to move in any direction without having to turn relative to the robot base. By using the transwheels, the mobile robot can execute a single sideways motion, and further can easily track a moving object while maintaining a required orientation with respect to it. The advantages of mobile robot using the transwheels are allowing continuous translation and rotation in any direction in competitive high-speed environments. Figure 3.5 shows the picture of the transwheels.

Figure 3.5: Transwheels

3.1.2 DC Geared Motor (MO-SPG-30-20K)

3 DC Geared Motor were used in order to rotate the transwheels individually. The model of the motor is MO-SPG-30-20K. I bought the motor from Cytron Technologies. The rated voltage is DC 12V and maximum current rating is 410mA. Additionally it stall current is 1.8 A. Furthermore, the feasible rated speed at 5200 RPM and rated torque at 5.88mNm were offered by this model of DC geared motor.

The unit price for this DC geared motor is RM 70. A pair of this product thus costs me RM 210. Figure 3.6 show the picture of a MO-SPG-30-20K DC geared motor.

Figure 3.6: A MO-SPG-30-20K DC geared motor

3.2 Electronic and Circuit Design

The first stage in electronic and circuit design is to understand the requirements of the project and the limitation of various constraints like the level of technology, reliability of microcontroller and the complexity of programming codes and interfacing devices. Intensive study on electronic components' datasheets was then conducted to compare and analyze the advantages and shortcoming of different electronic circuits and devices used by previous project researchers. After that, the most reliable and suitable circuits were designed and drawn in Proteus software. Finally, the circuit is made according to the circuit schematic designed. Subsections below discussed the design of circuits in detail.

This project uses PIC16F777 as the main controlling unit and DC geared motor to drive the transwheels individually. As the input, IR sensor is used. IR sensor will detect the line in order to make the mobile robot follow the line. To control the DC geared motor, motor driver L298N is used. Figure 3.7 shows the block diagram of the circuit design.

Figure 3.7: Block diagram of the circuit design

3.2.1 PIC Start Up Kit (SK40C)

PIC Start up Kit is enhanced 40 pins PIC is designed to offer an easy to start board for PIC. This board comes with basic element to begin project development. By using the SK40C, it is easier to do the circuit. All the I/O pins are nicely labeled to avoid miss-connection. It will not require extra component for the PIC to function. The connector for UIC00A is already assembled to load program. So, it is easy to re-programming, which is doesn’t have to plugging PIC out and back. To connect the I/O pins, just solder SK40C to board and plugging in the I/O components. Figure 3.8 shows the picture of the SK40C.

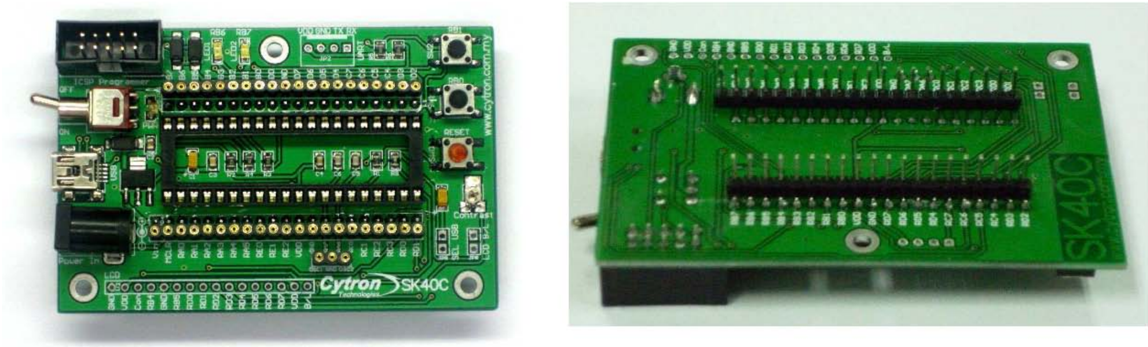


Figure 3.8: SK40C

3.2.2 LiPo Battery

Lithium Polymer or LiPo battery is a type of rechargeable battery that normally composed of several identical cells to boost up the voltage and current. One 11.1V LiPo batteries were used in this project. The model of the battery is Turnigy Nano-Tech 11.1V, 2200 mAh, and discharge rate at 35 C. The LiPo battery was used to drive all the circuit for my project which are PIC Start up Kit, IR sensor circuit, and motor driver circuit to drive motor. Figure 3.9 shows the image of the LiPo batteries that had been used.

Figure 3.9: LiPo Battery.

3.2.3 I/O Pin Assignation for PIC16F777

Microcontroller was used in this project due to its small sizing, low cost but high performance. A microcontroller is combination of a microprocessor, memory, I/O ports and other special function registers such as timer, ADC, PWM, interrupt etc. PIC16F777 was selected as it is readily available and easy to use. Figure 3.10 shows the picture of the PIC16F777.

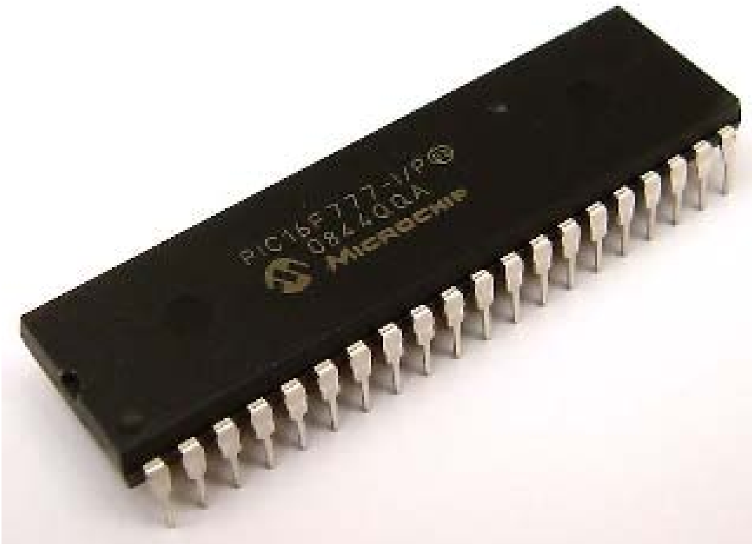


Figure 3.10: PIC16F777

PIC16F777 is used as the main controlling unit. It has 40 pin. It has the program memory up to 8k single-word instructions. It has 36 I/O which are port A, B. C. D and E. It also has 17 interrupts, 2 comparators and can control 3 PWM. This PIC is able to be used for this project since it has to control 3 DC geared motor.

The key features of PIC16F777 can be summarized as in Table 3.1 while the pin diagram of this microchip can be found in Figure 3.11.

Table 3.1: PIC16F777 device Features

Features	Description
Operating Frequency	DC – 20 MHz
Flash Program Memory (14-bit words)	8K
Data Memory (bytes)	368
Interrupts	17
I/O Ports	Ports A, B, C, D, E
Timers	3
Capture/Compare/PWM Modules	3
Master Serial Communications	MSSP, AUSART
Parallel Communications	PSP
10-bit Analog-to-Digital Module	14 Input Channels
Instruction Set	35 Instructions

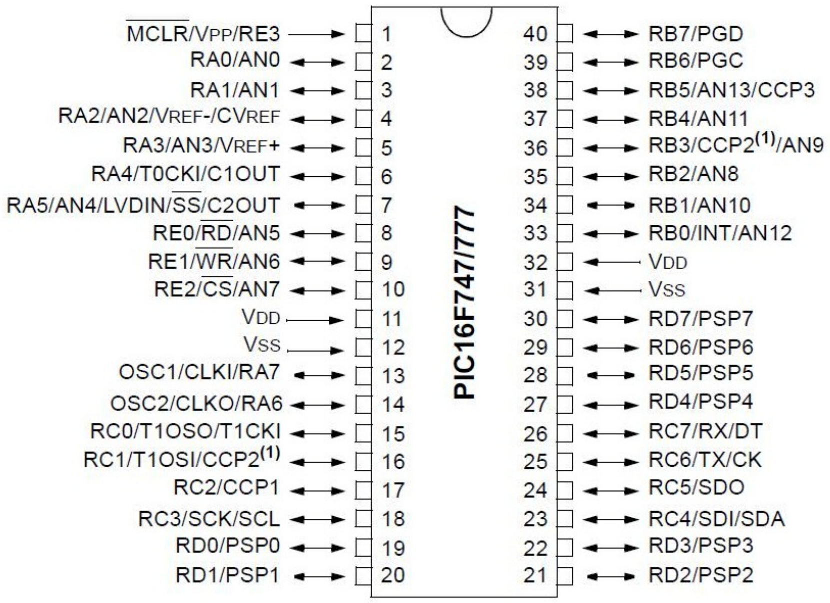


Figure 3.11: Pin Diagram of PIC16F777

After decided microcontroller to be used for this project, the I/O pin assignation for all components are determined. Figure 3.12 shows the I/O assignation for the main circuit.

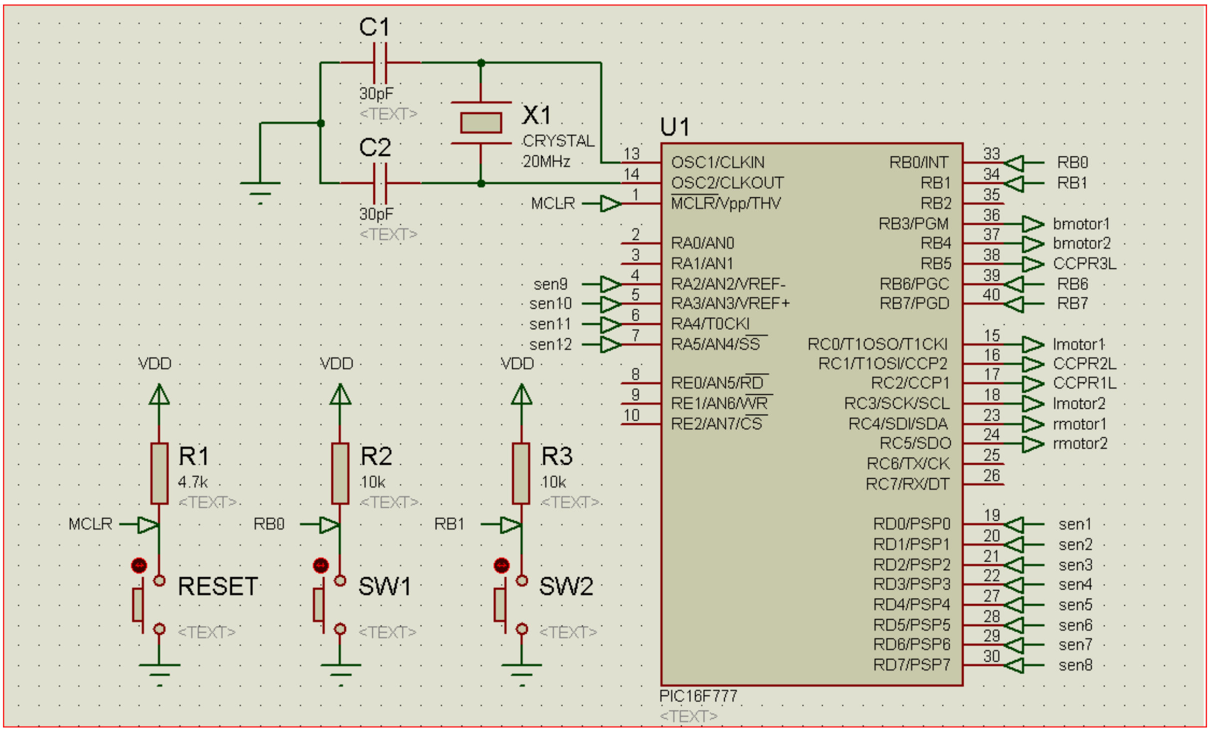


Figure 3.12: I/O Assignation for Main Circuit

3.2.4 Circuit Connection for DC Geared Motor's Motor Driver L298N

Motor driver L298N is used in the main circuit as the driving chip of three DC geared motors which provide the mobility of the mobile robot. This motor driver allows a total of 2A high current to pass through it during operation. This complies with the using of 12V DC geared motor. Furthermore, it is also a high voltage and current dual full-bridge driver that was designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids DC and even stepper motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage.

A motor driver L298N can drive up to 2 DC geared motor. Since I used 3 DC geared motor, so I need total of 2 motor driver L298N. Figure 3.13 Shows The Pin Diagram And Actual Look Of A L298N Motor Driver While Figure 3.14 Shows The Circuit Connection Of L298N In The Main Circuit.

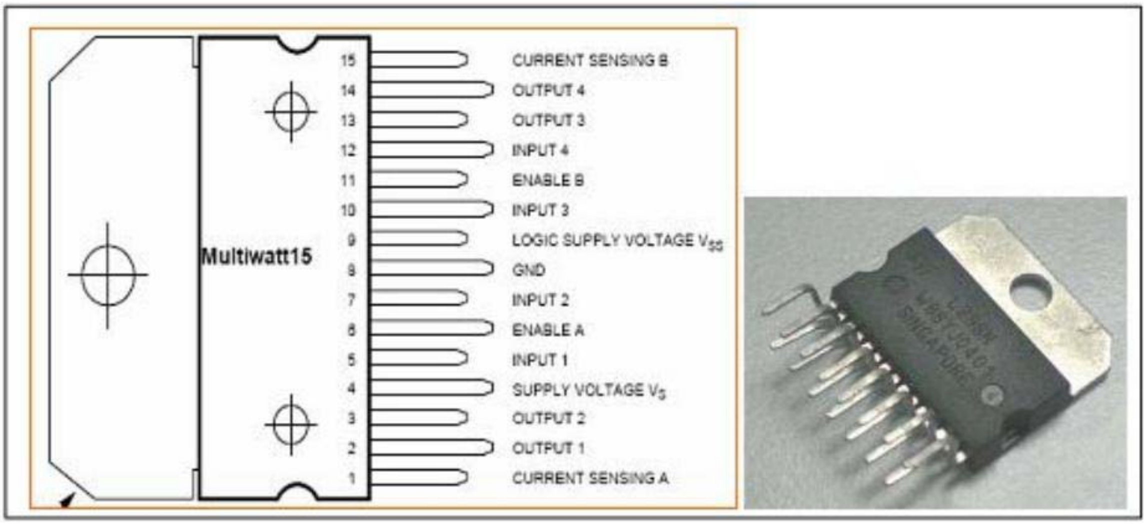


Figure 3.13: Pin Diagram and Actual Look of L298N Motor Driver

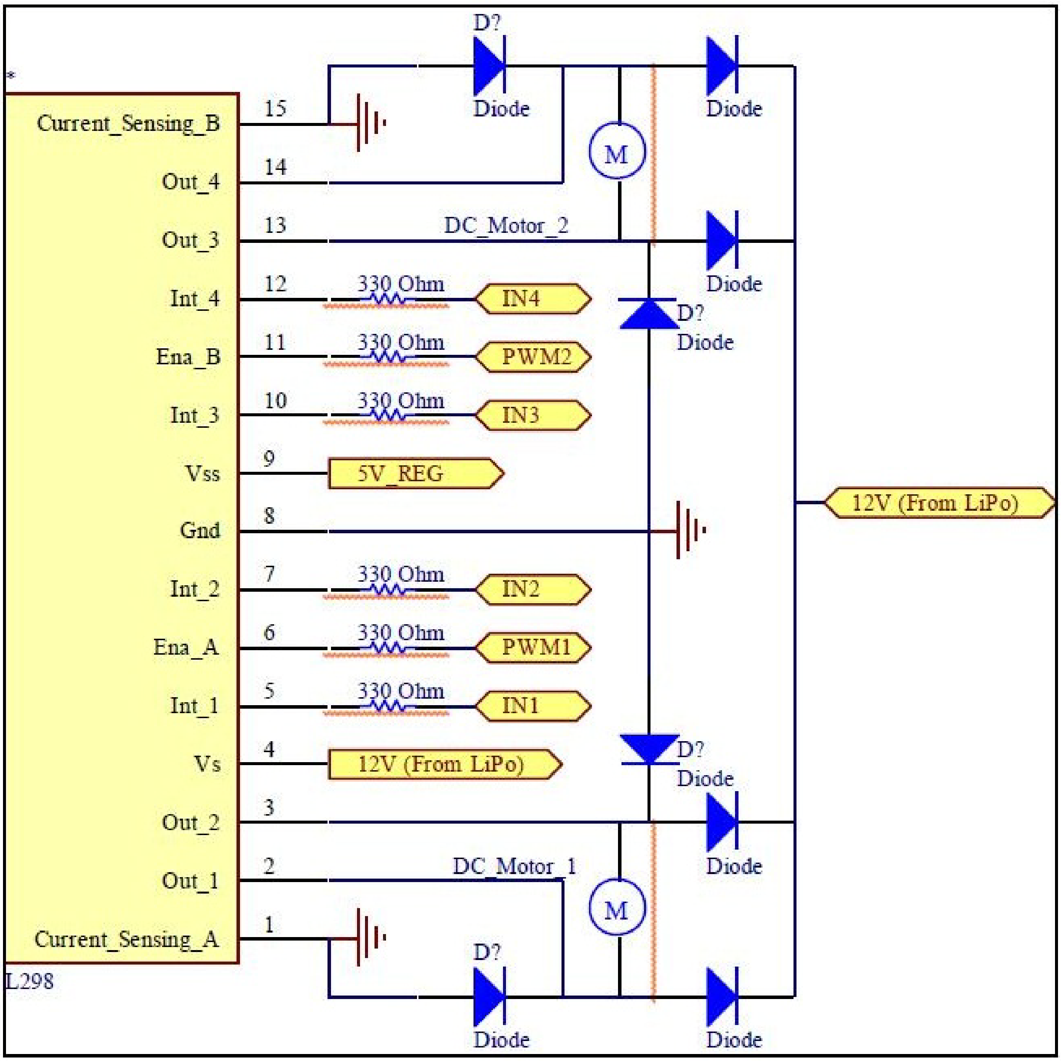


Figure 3.14: Circuit Connection of Motor Driver L298N

3.2.5 Circuit Connection of IR Sensors

Sensors used in line-tracking purpose were IR sensors which operate on the basis of photo resistivity. An IR sensor is composed of a transmitter and a receiver. The transmitter transmit infrared red light which is invisible for human being. The transmitted infrared red light will be reflected by a surface and received by the receiver. The IR receiver converts light intensity to its equivalent resistance and by using voltage division method, the equivalent TTR logic voltage from 0V to 5V is generated. Figure 3.15 and Figure 3.16 show the circuit design of IR sensors.

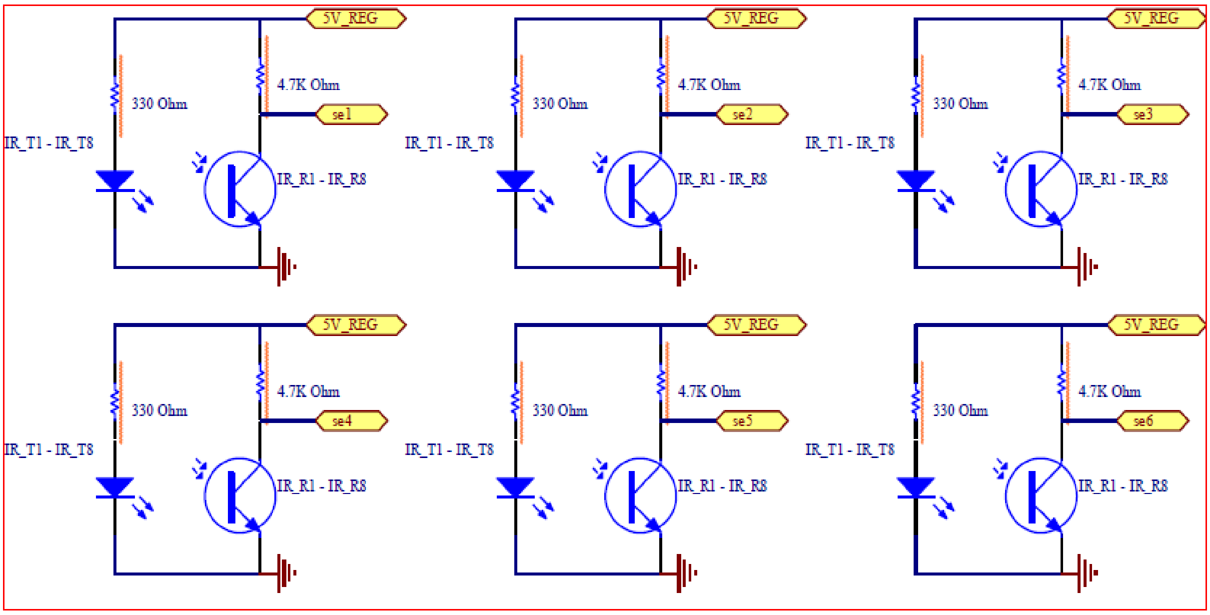


Figure 3.15: Circuit Connection of IR Sensors – Part A

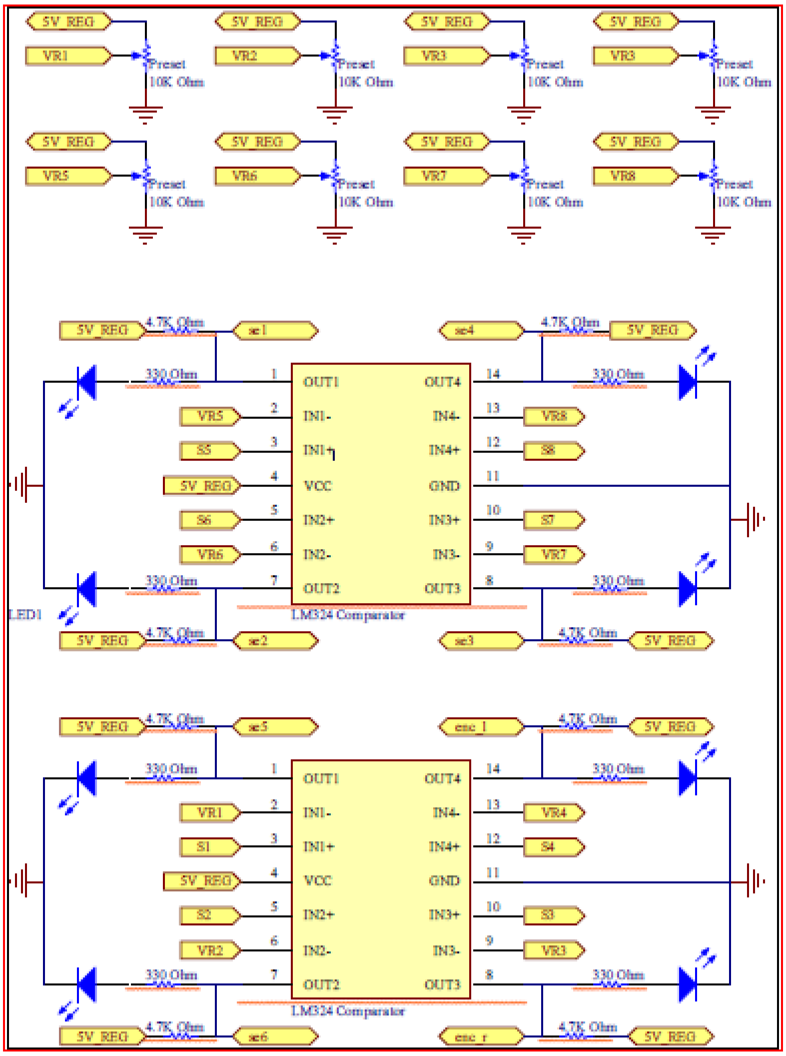


Figure 3.16: Circuit connection of IR Sensors – Part B

3.2.6 Combine All Circuit

After the electronic and circuit design process, hands on circuit making is carried out. Donut board was employed for all the circuits and modules designed due to its simplicity in circuit connection. Figure 3.17 shows the completed main circuit – SK40C and IR sensor circuit meanwhile Figure 3.18 shows the motor driver circuit. Lastly, Figure 3.19 shows all the circuit is mounted on the mobile base.

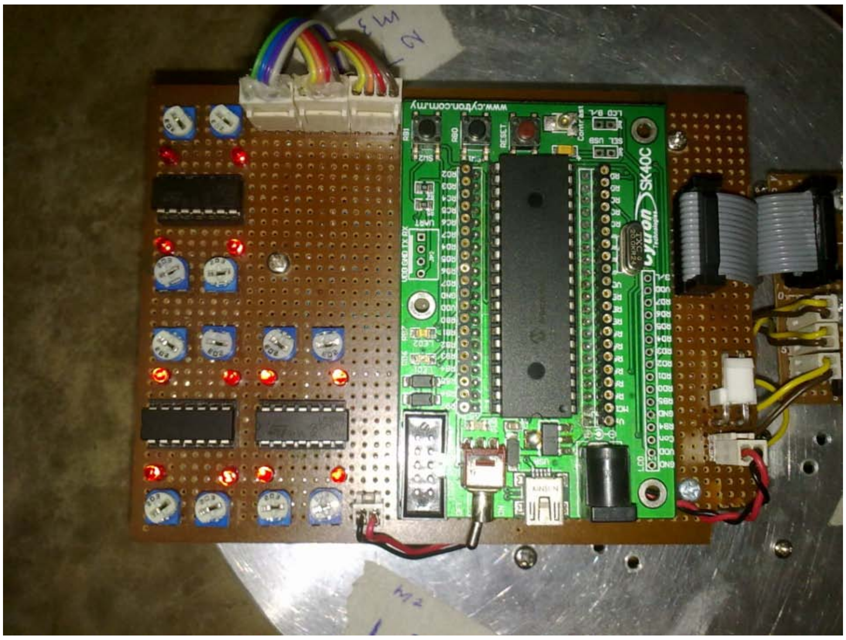


Figure 3.17: Main Circuit

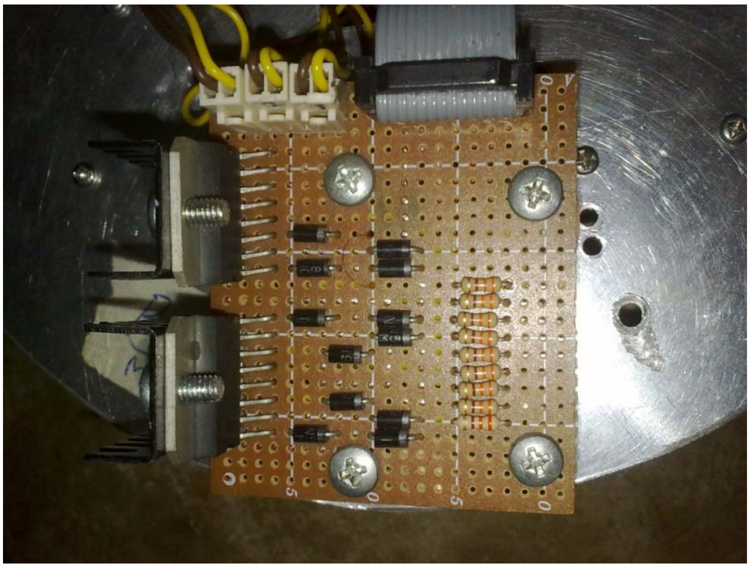


Figure 3.18: Motor Driver Circuit

Figure 3.19: All Circuit Mounted on Mobile Base

3.3 Programming Design

After completing the hardware and the electronic circuit for the robot, the attention was shift to programming design of the robot. The programming design of the robot is to control its movement in omni directional. The completed programs were then programmed into the PIC16F777 microcontrollers. Continuous debugging and compilation of the program were needed towards the completion of the programming design of the robot. The full programs for both controllers were attached in the appendix of this thesis.

C-language is chosen as the programming language for this project as the memory size needed for C-language programming is small and it is extremely easy to

understand. MPLAB IDE software developed by Microchip was employed to write the C-language program. For the compilation of the program, Microchip's C30 compiler is adopted.

Figure 3.20 to Figure 3.21 shows the main programming flow chart and line-following feature of the omni line following mobile robot

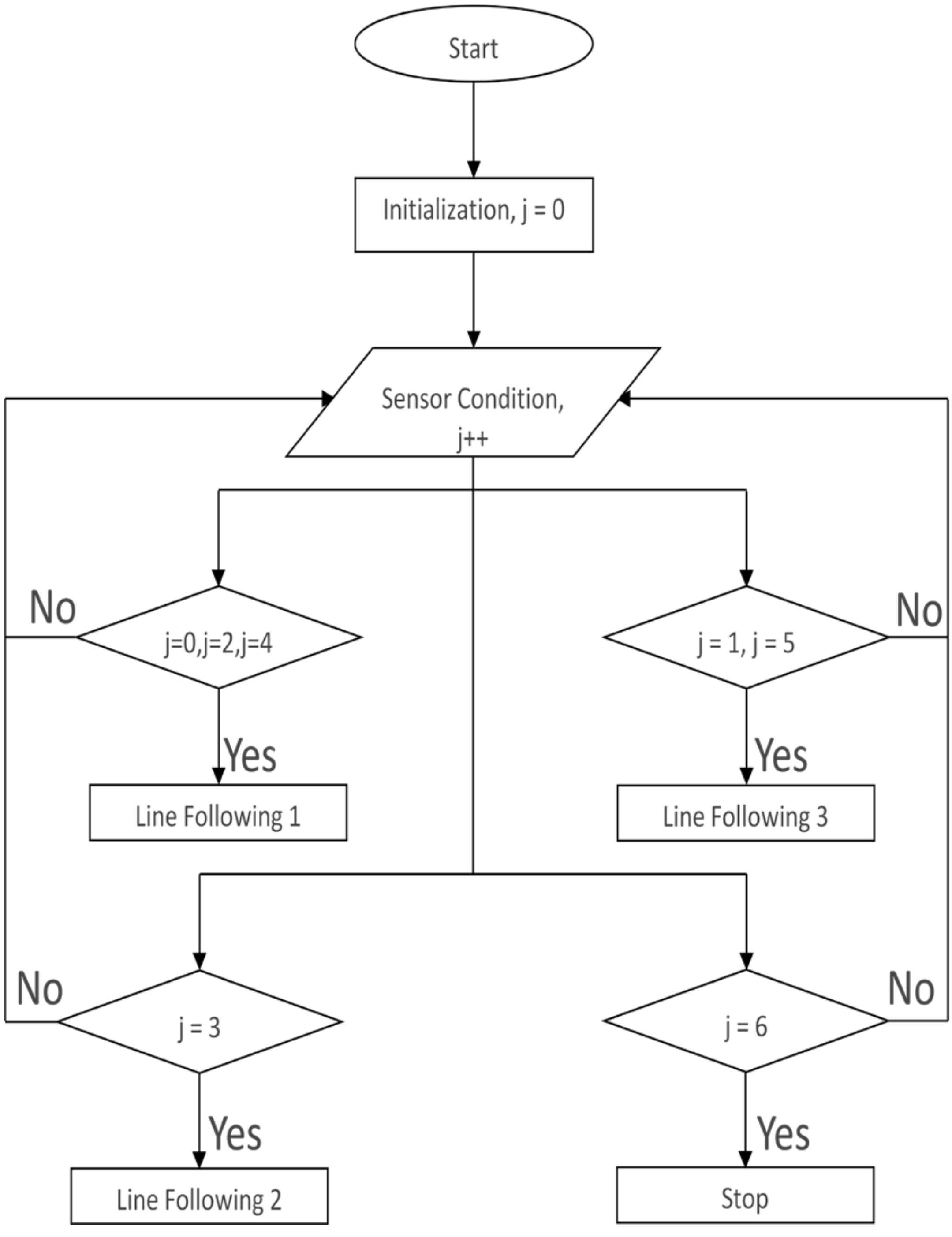


Figure 3.20: Flow Chart of Main Program

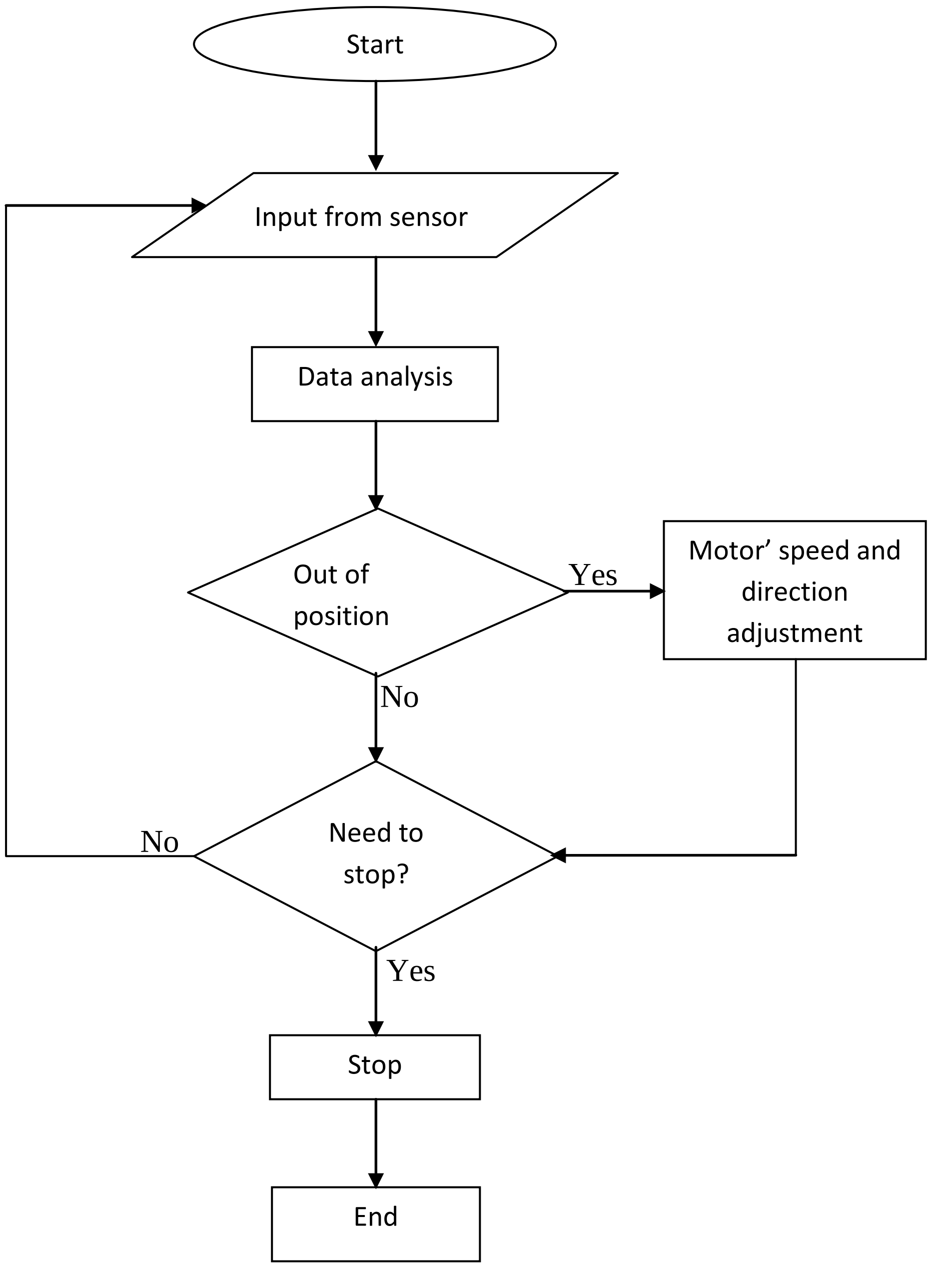


Figure 3.21: Flow Chart of Line Following

The mobile robot has the ability to detect the junction. When the sensor cross above the junction, the sensor condition will count up and execute the line following mode respective to the path assign in programming. Figure 3.22 show the condition to detect the junction.

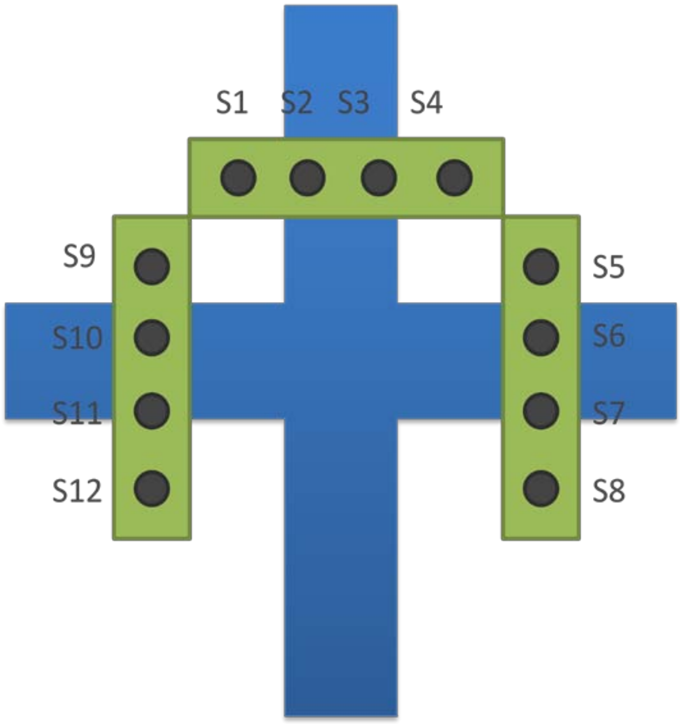


Figure 3.22: Sensor Condition to Detect Junction

When S2 or S3 and S6 or S7 and S10 or S11 above the line and receive the signal, the junction condition will be detected and counting up. S1 to S4 is front sensor to move forward, while S5 to S8 is right sensor to move to right and S9 to S12 left sensor to move to left.

Figure 3.23 below shows the path for the line following. The line following is already assigned to move in the respected direction. Line Following 1 is to move the mobile robot forward, while Line Following 2 is to move the mobile robot to the right and lastly Line Following 3 is to move the mobile robot to the right. Figure 3.24 shows the sensor for each of line following movement.

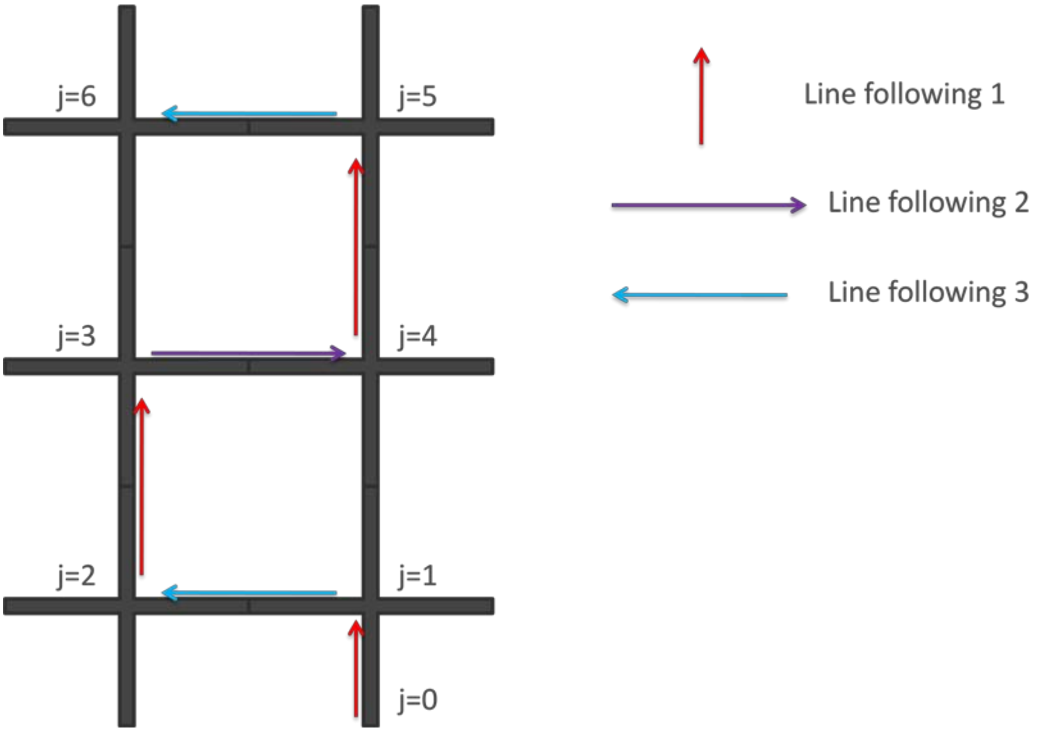


Figure 3.23: Path for the Line Following

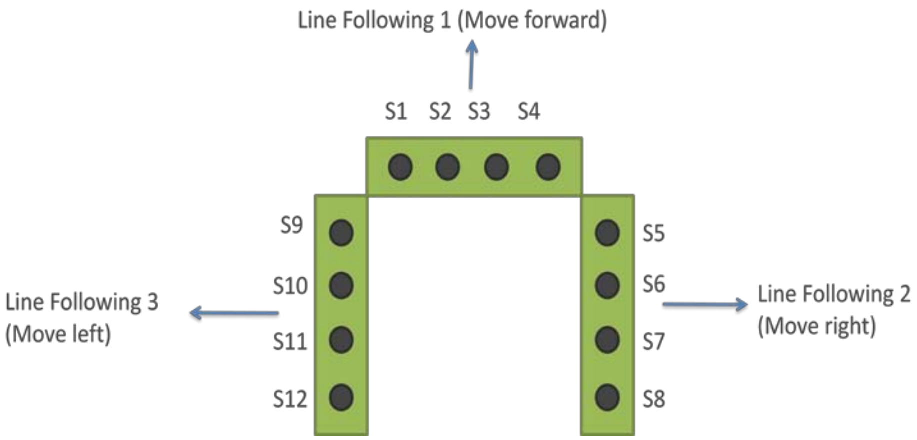


Figure 3.24: Sensor for the Line Following

3.4 Summary of Chapter 3

This chapter discussed about the mechanical design, electronic and circuit design and programming design of the Omni Directional Line Following Mobile Robot.

In mechanical design part, the mobile robot with the specification discussed above was successfully done. The types of motor used were also discussed in this part. In electronic and circuit design section, various electronic components, modules and circuits employed in this mobile robot were discussed including IR sensor, motor driver L298N and also the main circuit of the robot.

Finally in programming part, the selection for programming tools was determined and programming flow chart for main program and line-following of the Omni Line Following Mobile Robot were discussed.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Final Hardware Design

The final hardware design of the omni directional line following mobile robot is illustrated in Figure 4.1.

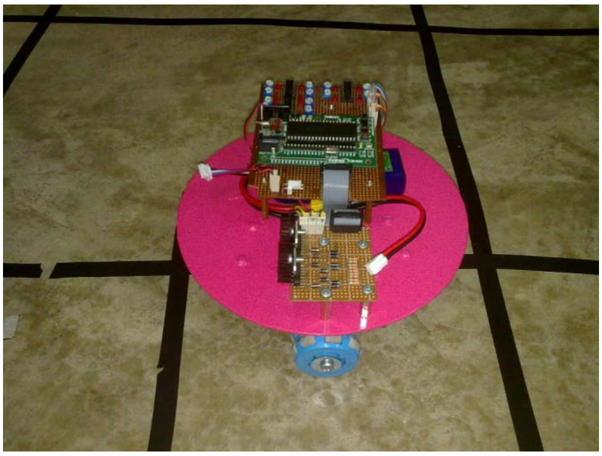


Figure 4.1: Final Hardware Design

The outlook of the omni directional line following mobile robot is very compact. The mobile robot is small in size, suitable as it function to move anywhere in small area. Table 4.1 presented the hardware specification of this mobile robot.

Table 4.1: Hardware Specification

Specification	Description
Radius	110 mm
Height	130 mm
Weight	3.0 kg
Actuators	3 DC Geared Motors
DOF	3 DOF
IR Sensor	12 IR sensors

4.2 Line Following Feature.

4.2.1 Omni Line Following

The integration of hardware and software design for omni directional and line following ability for the mobile robot were achieved successfully. The mobile robot is able to move in omni directional and able to track the black line made of 17 mm width black wire tape. By omni directional movement, the mobile robot doesn’t have to rotate its base when go through the junction. Figure 4.2 shows the step on how the mobile robot follows the line in omni directional movement.

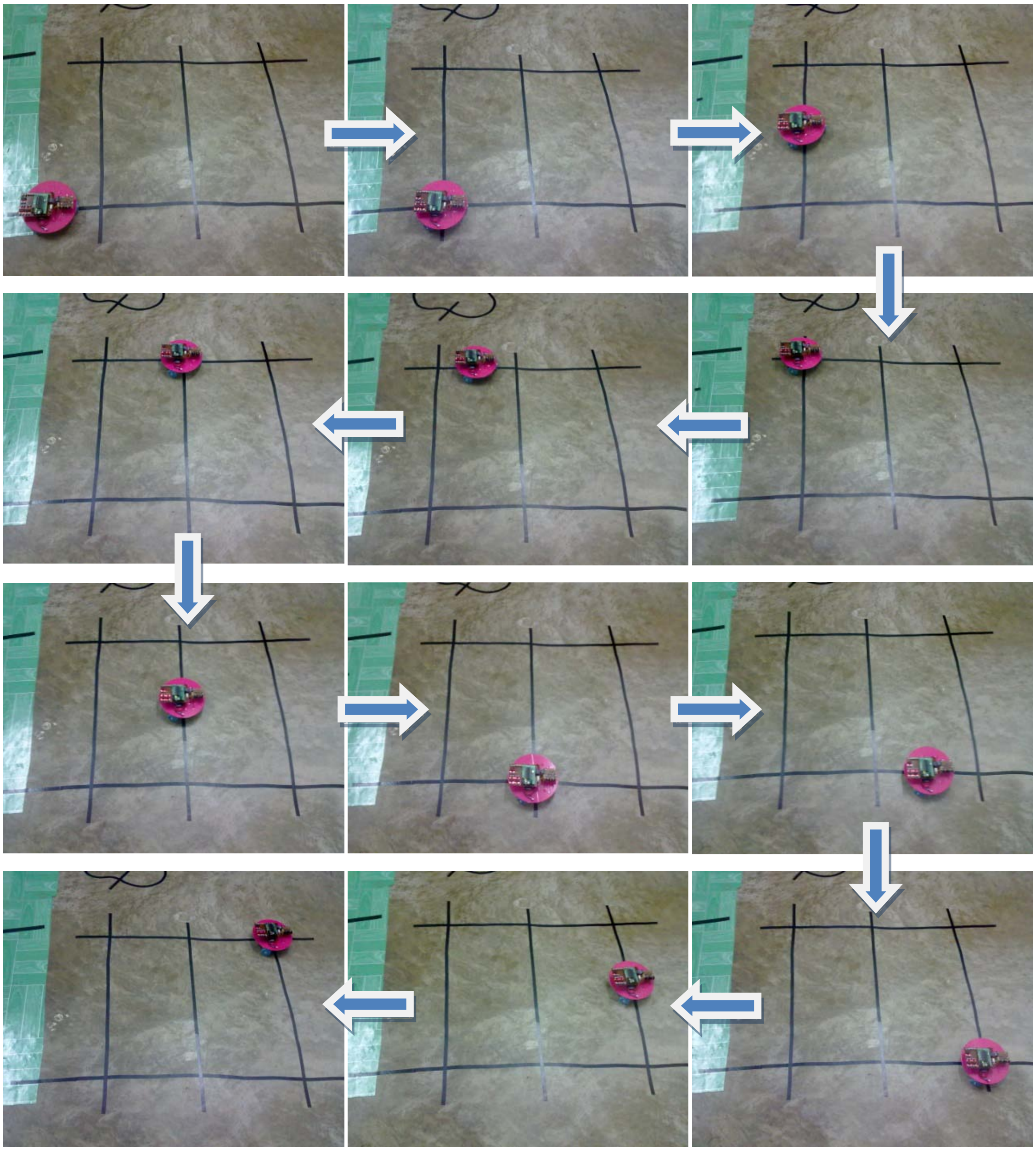


Figure 4.2: Step on How Mobile Robot Follows Line in Omni Directional Movement

4.2.2 Normal Line Following.

The mobile robot also can do the normal line following. Using the normal line following, the mobile robot needs to rotate its base when go through the junction. To make it simple, Figure 4.3 shows the normal line following features.

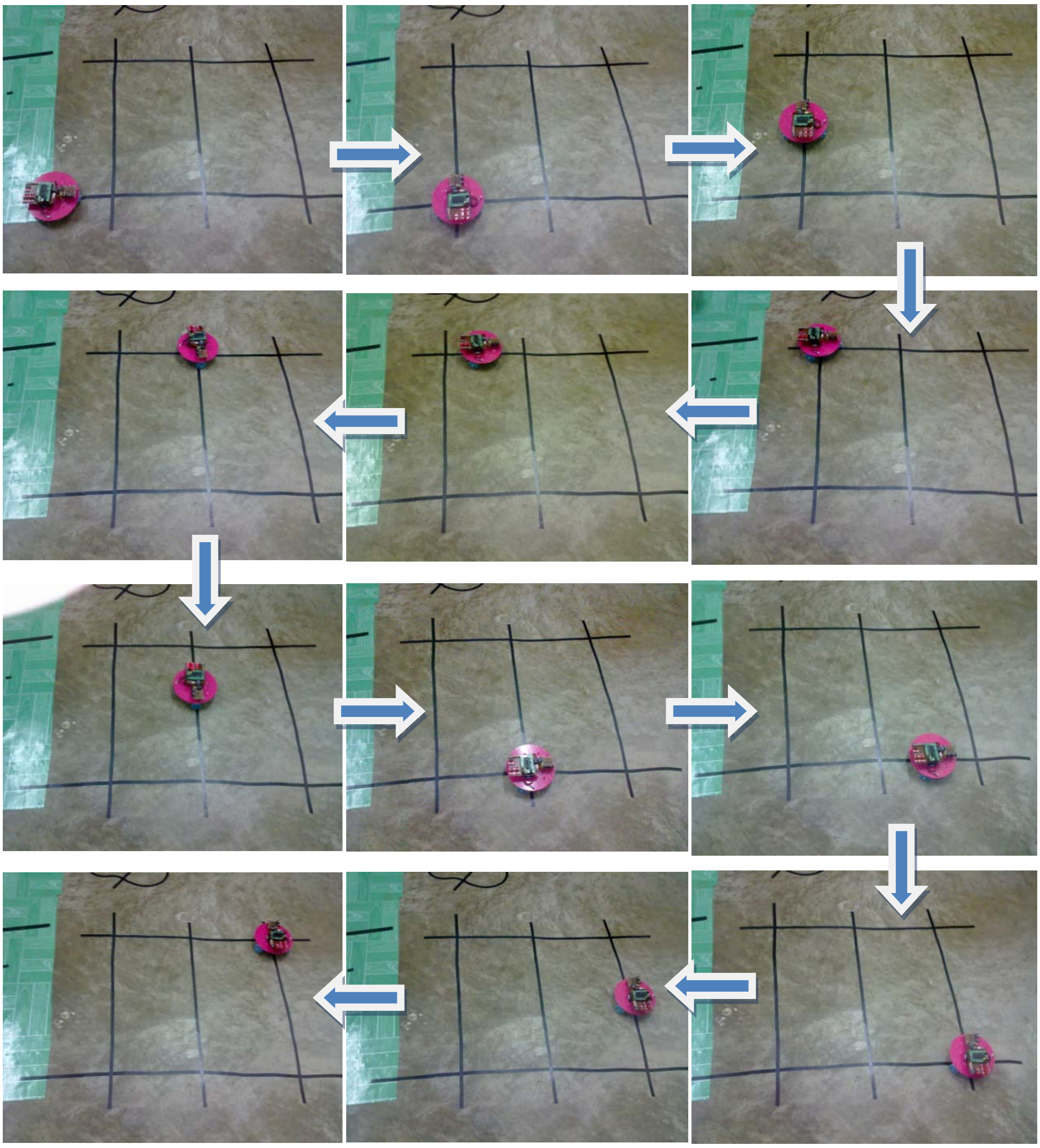
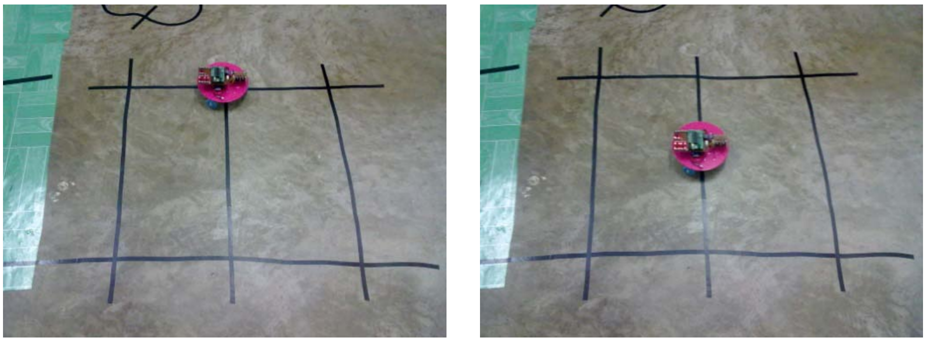


Figure 4.3: Step on How Mobile Robot Follows Line in Normal Movement.

4.2.3 Comparison between Omni Directional and Normal Movement

As mention before, in omni directional movement, the mobile robot doesn't have to rotate its base with respect to the direction it will move. But in normal movement, it has to rotate its base with respect to the direction it will move. Figure 4.4 will explain more about the comparison between omni directional and normal movement.



a) Omni Directional Movement

b) Normal Movement

Figure 4.4: Comparison between Omni Directional and Normal Movement

When comparing in term of time taken to reach the same destination and path, omni directional movement take less time to reach the destination, compare to normal movement. Table 4.2 shows the time taken of the mobile robot to reach the destination in omni directional and the normal movement.

Table 4.2: Time Taken to Reach the Destination

Reading	Omni Directional (s)	Normal (s)
1	5.59	6.85
2	5.41	6.74
3	5.89	7.32
4	5.33	6.91
5	5.74	7.01
Average	5.59	6.97

Based on the result, it is proven that omni directional takes less time to reach the destination based on its ability to turn relative to the robot base. The smoothness of the omni directional movement makes it more stable than the normal movement.

4.3 Summary of Chapter 4

This chapter discuss on the achievement of the Omni Directional Line Following Mobile Robot. This chapter discuss on every aspect which are hardware design and line following feature. To make it clear on what is omni directional movement, I have compare with the normal line following. Based on the explanation of both omni and normal line following, omni directional movement is more stable since it can move in any direction without having to turn relative to the robot base.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This project had effectively move in omni directional movement and at the same time can track black line and follow the black line in particular direction that has been assign to. It can be concluded that all the objectives in Chapter 1 are achieved by the end of this research. The Omni Directional Line Following Mobile Robot able to move in omni directional and follow the black line given.

5.2 Problem

During completing Omni Directional Line following Mobile Robot, there were several problems occurs.

First problem is to define omni directional movement. Because the movement is depending on the total vector by each transwheels, I have to find the movement algorithm. I have difficulties because of the unique position of transwheels which is 120° apart. I take more time to find the algorithm. I need to try and error until I get the right movement.

Last problem is to place the IR sensor so it will detect the black line and follow the black line. Total of 12 pair IR sensor is used in order to enable the line following ability. The problem is not on the line following movement, but the main problem is how it will detect the line and respond by moving in omni directional. From 12 pair of sensor, I divided it into 3 set of sensor; each set will have 4 pair of IR sensor.

Based on the 3 set of IR sensor, first idea, I make it in triangular shape. But it is not effective since I can't make it to move in omni directional. So I do the second idea, which is in square shape. Because I only have 3 set of sensor, so the square shape is incomplete. I remove the IR sensor at the bottom. The sensor placement can be referred at Figure 3.4. The sensor can detect the junction and can follow the black line.

5.3 Limitation

The mobile robot can detect cross junction only. Otherwise it will move in normal line following. The mobile robot has to detect the junction condition first and then it will process the next movement. Lastly the movement is already assigned in the programming based on the path given. So to move in other path, I have to reprogram based on the new movement I want.

5.4 Recommendation

For future development, it is recommended to use 4 transwheels design instead of 3 transwheels design. Using 4 transwheels design, its movement is more stable. Moreover, it is easier to find the movement algorithm. Another recommendation is to put position sensor like compass or gyro sensor. So this mobile robot has a reference relative to its base. To move, it doesn't have to rotate but only translate with respect to degree of the given point.

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8. L298 datasheet, 2000
9. http://www.youtube.com/
10. http://www.wikipedia.org/

APPENDIXES

APPENDIX A: Source Code for Omni Directional Line Following Mobile Robot

```
#include <pic.h>

//	configuration
//==========================================================
===============
__CONFIG(0x3FA2);
__CONFIG(0x3FBC);

unsigned char i=0,shift=0;
int j=0;
unsigned int k=0;
//	define
//==========================================================
===============
#define button1			RB0
#define button2			RB1

#define sen1		RD0				//sensor array back motor
#define sen2		RD1
#define sen3		RD2
#define sen4		RD3

#define sen5		RD4				//sensor array left motor
```

```
#define sen6        RD5
#define sen7        RD6
#define sen8        RD7

#define sen9        RA2                         //sensor array right motor
#define sen10       RA3
#define sen11       RA4
#define sen12       RA5

#define led1        RB6
#define led2        RB7

#define lmspeed         CCPR1L
#define lmotor1         RC0
#define lmotor2         RC3
#definermspeed          CCPR2L
#define rmotor1         RC4
#define rmotor2         RC5
#definebmspeed          CCPR3L
#define bmotor1         RB3
#define bmotor2         RB4



//      function prototype
//===========================================================
===============
void m_stop(void);
void lm_run(unsigned char dir);
void rm_run(unsigned char dir);
void bm_run(unsigned char dir);
void clockwise(void);
void anticlockwise(void);
void delay(unsigned long data);
```

```
void line_follow1(void);
void line_follow2(void);
void line_follow3(void);
void omni1(void);
void normal1(void);

void forward1(void);
void left1(void);
void right1(void);
void sharpleft1(void);
void sharpright1(void);

void forward2(void);
void left2(void);
void right2(void);
void sharpleft2(void);
void sharpright2(void);

void forward3(void);
void left3(void);
void right3(void);
void sharpleft3(void);
void sharpright3(void);

//      main function                          (main fucntion of the
program)
//=============================================================
===============
void main(void)
{
//setup ADC
ADCON1 = 0b00001111;

//set I/O input output
```

```
TRISA = 0b00111100;
TRISB = 0b00000011;
TRISC = 0b00000000;
TRISD = 0b11111111;

PORTA = 0;
PORTB = 0;
PORTC = 0;
PORTD = 0;
PORTE = 0;

//Setup up PWM operation
PR2=255;
CCP1CON = 0b00001100;
CCP2CON = 0b00001100;
CCP3CON = 0b00001100;
T2CON   = 0b00000100;
lmspeed = 0;
rmspeed = 0;
bmspeed = 0;

//program start
    while(1)
    {

        if(button1 == 0)                    //select mode
        {
            i+=1;                                   //local variable i
plus one
            if(i==)i=0;                     //when local variable i
reach three,set it back to zero
            while(button1 == 0)             //loop to filter the switch
            {
            delay(10000);
```

```
                }
            }
            if(button2 == 0)                    //execute to the selected
mode
            {
            while(button2 == 0)             //loop to filter the switch
            {
            delay(10000);
            }
            switch(i)
                {
                        case 1:omni1();
                        case 2:normal1();
                        break;
                }
            }

        }
}

void omni1(void)
{
        while(i==1)
        {
        led1^=1;
                if ((j==0)||(j==2)||(j==4)){
                for(k=0;k<10000;k++)
                    line_follow1();
                while(1){
                    line_follow1();
                    if
(((sen2==1)||(sen3==1))&&((sen6==1)||(sen7==1))&&((sen10==1)||(sen11==1))){
            //sensor junction condition
                        j++;
```

```
m_stop();
break;
}
}
}
if ((j==1)||(j==5)){
for(k=0;k<10000;k++)
line_follow3();
while(1){
line_follow3();
if
(((sen2==1)||(sen3==1))&&((sen6==1)||(sen7==1))&&((sen10==1)||(sen11==1))){
j++;
m_stop();
break;
}
}
}
if ((j==3)){
for(k=0;k<10000;k++)
line_follow2();
while(1){
line_follow2();
if
(((sen2==1)||(sen3==1))&&((sen6==1)||(sen7==1))&&((sen10==1)||(sen11==1))){
j++;
m_stop();
break;
}
}
}

if(j==6)
{
```

```
                    for(k=0;k<10000;k++)
                        m_stop();
                    }


                }
}



void normal1(void)
{
    while(i==2)
    {
    led2^=1;
                    if ((j==0)||(j==3)||(j==4)){
                    for(k=0;k<10000;k++)
                        line_follow1();
                    while(1){
                        line_follow1();
                        if
(((sen2==1)||(sen3==1))&&((sen6==1)||(sen7==1))&&((sen10==1)||(sen11==1))){
                            j++;
                            m_stop();
                            lmspeed=rmspeed=bmspeed=200;
                            lm_run(0);
                            rm_run(0);
                            bm_run(0);
                            delay(30000);
                            break;
                        }
                    }
                    }
                    if ((j==1)||(j==2)){
                    for(k=0;k<10000;k++)
                        line_follow1();
```

```
while(1){
        line_follow1();
        if
(((sen2==1)||(sen3==1))&&((sen6==1)||(sen7==1))&&((sen10==1)||(sen11==1))){
                j++;
                m_stop();
                lmspeed=rmspeed=bmspeed=200;
                lm_run(1);
                rm_run(1);
                bm_run(1);
                delay(30000);
                break;
        }
}
}
if ((j==5)){
for(k=0;k<10000;k++)
        line_follow1();
while(1){
        line_follow1();
        if
(((sen2==1)||(sen3==1))&&((sen6==1)||(sen7==1))&&((sen10==1)||(sen11==1))){
                j++;
                m_stop();
                break;
        }
}
}

if(j==6)
{
for(k=0;k<10000;k++)
        m_stop();
}
```

```
                }
}

//line following 1 mode
//==============================================================
==========================================================
void line_follow1(void)
{
                unsigned char memory;

                if((sen4==0)&&(sen3==0)&&(sen2==0)&&(sen1==1))
                //0001
                        {sharpright1();memory = PORTD&0b11111111;}

                else if((sen4==0)&&(sen3==0)&&(sen2==1)&&(sen1==0))
                //0010
                        {right1();memory = PORTD&0b11111111;}

                else if((sen4==0)&&(sen3==0)&&(sen2==1)&&(sen1==1))
                //0011
                        {right1();memory = PORTD&0b11111111;}

                else if((sen4==0)&&(sen3==1)&&(sen2==0)&&(sen1==0))
                //0100
                        {left1();memory = PORTD&0b11111111;}

                else if((sen4==0)&&(sen3==1)&&(sen2==1)&&(sen1==0))
                //0110
                        {forward1();memory = PORTD&0b11111111;}

                else if((sen4==1)&&(sen3==0)&&(sen2==0)&&(sen1==0))
                //1000
                        {sharpleft1();memory = PORTD&0b11111111;}
```

```
		else if((sen4==1)&&(sen3==1)&&(sen2==0)&&(sen1==0))
		//1100
			{left1();memory = PORTD&0b11111111;}

		else if((sen1==0)&&(sen2==0)&&(sen3==0)&&(sen4==0))
		//0000
			{
				if ((memory == 0b00000001)||(memory ==
0b00000011)||(memory == 0b0000010))
				{
					sharpright1();
				}
				else if ((memory == 0b00001000)||(memory ==
0b00000100)||(memory == 0b00001100))
				{
					sharpleft1();

				}
			}

}



//line following 2 mode
//==============================================================
==========================================================
void line_follow2(void)
{
		unsigned char memory;



		if((sen8==0)&&(sen7==0)&&(sen6==0)&&(sen5==1))
		//0001
			{sharpright2();memory = PORTD&0b11111111;}
```

```
else if((sen8==0)&&(sen7==0)&&(sen6==1)&&(sen5==0))
//0010
        {right2();memory = PORTD&0b11111111;}

else if((sen8==0)&&(sen7==0)&&(sen6==1)&&(sen5==1))
//0011
        {right2();memory = PORTD&0b11111111;}

else if((sen8==0)&&(sen7==1)&&(sen6==0)&&(sen5==0))
//0100
        {left2();memory = PORTD&0b11111111;}

else if((sen8==0)&&(sen7==1)&&(sen6==1)&&(sen5==0))
//0110
        {forward2();}

else if((sen8==1)&&(sen7==0)&&(sen6==0)&&(sen5==0))
//1000
        {sharpleft2();memory = PORTD&0b11111111;}

else if((sen8==1)&&(sen7==1)&&(sen6==0)&&(sen5==0))
//1100
        {left2();memory = PORTD&0b11111111;}

else if((sen5==1)&&(sen6==1)&&(sen7==1)&&(sen8==1))
//1111
        {forward2();}

else if((sen5==0)&&(sen6==0)&&(sen7==0)&&(sen8==0))
//0000
        {
                m_stop();
        }
```

```
}


//line following 3 mode
//==============================================================
==========================================================
void line_follow3(void)
{
            unsigned char memory;


            if((sen9==0)&&(sen10==0)&&(sen11==0)&&(sen12==1))
            //0001
                  {sharpright3();memory = PORTA&0b00111100;}

            else if((sen9==0)&&(sen10==0)&&(sen11==1)&&(sen12==0))
            //0010
                  {right3();memory = PORTA&0b00111100;}

            else if((sen9==0)&&(sen10==0)&&(sen11==1)&&(sen12==1))
            //0011
                  {sharpright3();memory = PORTA&0b00111100;}

            else if((sen9==0)&&(sen10==1)&&(sen11==0)&&(sen12==0))
            //0100
                  {left3();memory = PORTA&0b00111100;}

            else if((sen9==0)&&(sen10==1)&&(sen11==1)&&(sen12==0))
            //0110
                  {forward3();}

            else if((sen9==1)&&(sen10==0)&&(sen11==0)&&(sen12==0))
            //1000
```

```
                {sharpleft3();memory = PORTA&0b00111100;}

            else if((sen9==1)&&(sen10==1)&&(sen11==0)&&(sen12==0))
            //1100
                {sharpleft3();memory = PORTA&0b00111100;}

            else if((sen9==1)&&(sen10==1)&&(sen11==1)&&(sen12==1))
            //1111
                {forward3();}

            else if((sen9==0)&&(sen10==0)&&(sen11==0)&&(sen12==0))
            //0000
                {
                    m_stop();
                }


}



// Motor Control function
//==============================================================
===============
void m_stop(void)

{
    lmotor1=0;
    lmotor2=0;
    rmotor1=0;
    rmotor2=0;
    bmotor1=0;
    bmotor2=0;
}
```

```
void lm_run(unsigned char dir)
{
	lmotor1=dir;

	lmotor2=!dir;

}

void rm_run(unsigned char dir)
{
	rmotor1=dir;

	rmotor2=!dir;

}

void bm_run(unsigned char dir)

{
	bmotor1=!dir;

	bmotor2=dir;

}


void clockwise(void)
{
	lmspeed=rmspeed=bmspeed=255;
	lm_run(1);
	rm_run(1);
	bm_run(1);
}
```

```
void anticlockwise(void)
{
	lmspeed=rmspeed=bmspeed=255;
	lm_run(0);
	rm_run(0);
	bm_run(0);
}

//line following 1
//============================================================
==============================================

void forward1(void)
{
	lmspeed=rmspeed=230;
	bmspeed=0;
	lm_run(0);
	rm_run(1);
}

void right1(void)
{
	lmspeed=180;
	rmspeed=216;
	bmspeed=180;
	lm_run(0);
	rm_run(1);
	bm_run(1);
}

void left1(void)
{
	rmspeed=180;
	lmspeed=216;
```

```
    bmspeed=180;
    lm_run(0);
    rm_run(1);
    bm_run(0);
}

void sharpleft1(void)
{
    lmspeed=220;
    rmspeed=220;
    bmspeed=220;
    lm_run(0);
    rm_run(0);
    bm_run(0);
}

void sharpright1(void)
{
    lmspeed=220;
    rmspeed=220;
    bmspeed=220;
    lm_run(1);
    rm_run(1);
    bm_run(1);
}


//line following 2
//==================================================================
==================================================

void forward2(void)
{
    lmspeed=180;
```

```
        rmspeed=180;
        bmspeed=240;
        lm_run(0);
        rm_run(0);
        bm_run(1);
}

void right2(void)
{
        lmspeed=0;
        rmspeed=200;
        bmspeed=220;
        rm_run(0);
        bm_run(1);
}

void left2(void)
{
        lmspeed=220;

        rmspeed=0;
        bmspeed=220;
        lm_run(0);

        bm_run(1);
        rm_run(0);
}


void sharpleft2(void)
{
        lmspeed=200;
        rmspeed=200;
        bmspeed=200;
```

```
	lm_run(0);
	rm_run(0);
	bm_run(0);
}

void sharpright2(void)
{
	lmspeed=200;
	rmspeed=200;
	bmspeed=200;
	lm_run(1);
	rm_run(1);
	bm_run(1);
}


//line following 3
//=============================================================
===============================================

void forward3(void)
{
	lmspeed=180;
	rmspeed=180;
	bmspeed=240;
	lm_run(1);
	rm_run(1);
	bm_run(0);
}

void right3(void)
{
	lmspeed=0;
	rmspeed=220;
```

```
        bmspeed=220;
        rm_run(1);
        bm_run(0);
}

void left3(void)
{
        lmspeed=220;

        rmspeed=0;
        bmspeed=220;
        lm_run(1);

        bm_run(0);
        rm_run(0);
}

void sharpleft3(void)
{
        lmspeed=200;
        rmspeed=200;
        bmspeed=200;
        lm_run(0);
        rm_run(0);
        bm_run(0);
}

void sharpright3(void)
{
        lmspeed=200;
        rmspeed=200;
        bmspeed=200;
        lm_run(1);
        rm_run(1);
```

```
	bm_run(1);
}

//	delay functions
//==============================================================
===============
void delay(unsigned long data)
{

	for( ;data>0;data-=1);
}
```